ROPES KNOTS and SLINGS for CLIMBERS

by

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La Siesta Press

Ropes, Knots & Slings
for
Climbers

Revised Edition

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La Siesta Press
1982

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A climbing manual is not a substitute for climbing practice or skill. Proper equipment will tend to make rockclimbs safer, but only if safety policies are always practiced. It is urged that inexperienced mountaineers will avail themselves of the instruction and guidance that the climbing groups of our various mountaineering clubs are so willing to supply to serious students of the climbing arts.

La Siesta Press
Box 406
Glendale, California, 91209
PRINTED IN U. S. A.

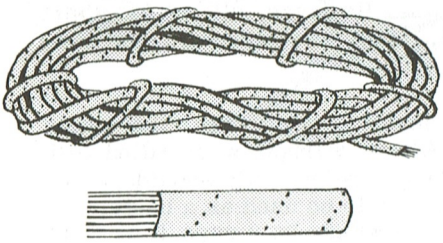
Preface

Some fifteen years ago, Leonard and Wexler in their basic work, "Belaying the Leader", published the first complete analysis of our climbing equipment. Since that time, climbing equipment has been greatly improved. Climbing rope breaking strength has grown from 3700 lbs. to 5500 lbs. with the development of new nylon yarn and constructions. Carabiners can now be had that test at 4500 lbs., rather than the 2200 lbs. of 1944. Other new synthetics are coming into use. Webbing, at first considered unusable, is finding many uses. Slings and harnesses are now standard devices in technical climbing. Nevertheless, except for isolated articles in mountaineering journals, nothing has been available on these developments.

We have endeavored to compile and supply information on these new materials and techniques. European and American ropes and methods are discussed and the advantages of each indicated.

Good climbing,

W. W.



kernmantal rope

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Introduction

Half Dome c.1870

MOUNTAIN climbing and rope-work have been closely aligned since the beginning of the sport. Reports of the first recorded alpine ascent, that of Mont Aiguille, do not mention the techniques used, but when Cortez sent his men to scale Popocatepetl and to descend into the crater, ropes were used both to lower the soldiers into the crater and to pull the partially suffocated men out again.

While this was not a climb for sport, but to obtain sulphur to make gunpowder, it did establish an altitude record that was to stand for over 300 years.

In early climbing, the ropes carried were quite short compared to those now considered desirable by modern standards. The most skilled climber led and either scrambled or was pushed up a ledge. He then lowered the rope for the remaining members of the party. They then either climbed the rope or were bodily hauled up. With the start of guided climbing, especially where the fee was drastically cut if the *patron* failed to reach his summit, undoubtedly many were literally dragged to the top by the guide's rope.

Early accounts of climbs in the Alps are filled with stories of a guide forming a loop in the end of his rope, then attempting to throw it over a rocky protuberance. If successful, the guide would climb hand over hand to the summit, and then assist his patron up with the same rope.

The early climbers learned of the hazards of the glacier crevasses and almost as soon learned it was convenient to be tied to a rope that could be used to lift a victim from the icy depths. However, often a too short rope would be used and when one fell, the others were dragged down too; an undesirable use for the rope.

With the "Golden Age of Climbing", a hundred years ago, the great climbing centers of Zermat and other Alpine villages were filled with guides and climbers, each with a climbing rope over his shoulder, almost as a badge of office. A rope was only to be used as a belay, not as a climbing aid. One just did not put his weight on a rope if he were a worthy member of the Alpine Club. It could be used to aid a descent and in the case of emergency or for safety, but each climber was expected to climb his own peak. It is just possible that quite a few tourists were still dragged to the summits by their guides and porters.

During this period, the study of climbing equipment more nearly approached a science. As early as 1864, the Alpine Journal carried an article discussing the various types of climbing ropes. Hemp, flax and cotton are European grown fibers that were used. Manila from the Philippines and sisal from Mexico gradually replaced these. There were discussions of the maximum size for usable strength, the minimum size to save weight and the advantages of various lays and number of strands. At the beginning of World War II, the contest had but two candidates left, a dense three-strand balloon manila and a similar four-strand yachting rope. A 7/16 " rope was now considered to be the standard size.

In the early 1930s, the use of pitons and other mechanical anchors led to the development of *tension* climbing -- climbing that required the use of ropes as necessary implement of climbing -- rather than as a security measure; what came to known as 'direct aid' climbing.

With the formation of the U.S. Mountain Troops, a determined investigation was made to secure the best possible rope. Manila, flax and hemp were in short supply as imported fibers. Sisal, distinctly weaker than manila, was not considered desirable. Extensive testing under Arnold Wexler at the Bureau of Standards proved that for strength, elasticity and aging characteristics, nylon was vastly superior. While much more expensive for the initial cost, nylon rope became *the* climbers rope as soon as it became available for civilian use.

In recent years, improved methods of treating and manufacturing nylon fibers and ropes have still further increased the breaking strength of these ropes. Just recently nylon webbing has been found to have advantages for slings and body harnesses and will likely displace rope for these purposes.

Ropes

The first ropes were invented before the beginning of written history. Certainly the first *assist* in climbing was a hanging grapevine, a natural rope. Strangely enough the construction of this *rope*, a core of very long fibers, covered with an outer sheath of the vine, is identical with the most modern of ropes, the *kernmantal* lines, now used extensively in Europe. We are sure that ropes predate written history, as one of the earliest means of recording numbers was by tying a series of knots in a cord.

In addition to these natural fibers, leather or hide ropes were early used, in fact the rawhide lariat has been used in the Southwest until within the most recent years. Other ropes were made of horsehair, a quite long fiber. Legends tell of times when under emotional stresses or for religious reasons, numbers of women would sacrifice their lovely tresses, to be spun into a wondefully fine and soft rope.

Cotton fibers have been used for ropes and make a rope that is easy to handle and is soft to the touch. Unfortunately cotton fibers are very short, running from about a half inch to two inches, and except for certain nautical uses, where the pleasing appearance of a cotton rope was desired, the only common use was for small braided lines.

Flax, hemp, sisal and manila became the fibers used in standard commercial ropes. While hemp was considered the desirable rope for climbing in the middle of the nineteenth century, the comparatively longer fibers of *manila*, technically *musa textilis* displaced its competitors. Only when imports were blocked by globular wars, was the Central American fiber sisal, substituted for it.

Since all natural fibers are short in length, ranging from a half inch for some cottons to a few feet for the tropical plants, it was necessary to first spin the fibers into yarns. These loosely bunched groups of strands then could be twisted more tightly to form strings or twines, or woven into groups of strands to form ropes. Originally, long sheds the length of the completed rope, were built. Men would walk back and forth along the ropewalks, slowly adding fibers until a rope was completed. Ropewalks were one of the first industries in the New World. With the coming of the machine-age, mechanisms were constructed that accepted a bundle of combed fibers at one end and would deliver a coil of rope at the other. Such continuous machines enabled cordage manufacturers to supply ropes in standard lengths of 1200 feet and even longer on special order.

To make a more stable and easier handling rope, manila ropes are treated with oily compounds during their manufacture. This lubrication or tarring provides the odor so noticable when a new coil of rope is first opened. The loss of these oils, as a rope ages, is a cause in the loss of strength in older ropes.

Attempts were made to provide a stronger manila rope. The use of the best fibers, commonly conceded to be *abaca* was a must for climbing ropes. There was much discussion of the advantages of three-strand *balloon* rope and of four strand *yachting* rope. By 1940, a long fiber hard dense laid 7/16 inch rope had become the standard climbing rope.

With the development of synthetic fibers, attempts were made to use these. Some of the first, such as rayon, proved unsuccessful, having a low tensile strength and deteriorating rapidly with age and exposure. The production of nylon promised a possibility of a better line. At the beginning of World War II and with the formation of the U. S. Mountain Troops, The Bureau of Standards' tests definitely proved the superiority of nylon.

TABLE I

PHYSICAL PROPERTIES OF 7/16" CLIMBING ROPES.

	MANILA	NYLON-1942	NYLON-1959
Breaking Strength (Max. load at break, pounds; stretch rate: 4 in./min.)			
Dry Test Conditions:	2500	3680	4575
Wet Test Conditions:	2620	3020	3900
Elongation to Failure (percent of free length)			
Dry Test Conditions:	12%	55%	48%
Wet Test Conditions:	19%	60%	49%
Abrasion over Rough Bar (percent of strength, after 25 cycles over 1½" iron pipe):	64%	72%	71%
Abrasion over Smooth Bar (over 3/8" bar, carabiner; pounds)	1250	2915	2796
Water Absorbtion (percent gained 24 hr. soaking):	57%	29%	29%

Sources: adapted from BELAYING THE LEADER, AN OMNIBUS OF SAFETY: Sierra Club, 1956 and SUMMIT MAGAZINE, November 1958.

In general, nylon has over twice the strength of manila rope. The cost may be four times that of a manila line, but the life of a manila rope is hardly one short climbing season. Rot and mildew are no problem with nylon. When nylon is abraded, it forms a protective fuzzy surface that reduces further abrasion. All synthetic fibers are affected by the ultra-violet radiation present in sunlight. However, it does not become a serious problem unless the fiber is exposed for days at a time. Recently it has been shown that useage is a greater hazard than aging. Tests have proven that a nylon rope may lose 20% of its overall strength with 100 days of use. Keep track of your climbing days on each rope!

Dacron ropes have been used to some extent for climbing. However its elongation under load is much less than that of nylon or perlon, being approximately that of manila. Since the ability of a line to absorb the shock of a falling climber is a very important factor, dacron has been rejected by alpinists. Its lack of stretch makes it valuable for static lines. The breaking strength is about 75% of that of nylon or perlon.

Polyethylene is another synthetic fiber that is used to manufacture ropes. It has the amazing ability to float in water, and hence is much used for water skiing. For this purpose, it is usually dyed a bright yellow. It is manufactured from much coarser filaments (0.012"). It possesses remarkable resistance to abrasion, being almost impossible to even cut with a pocket knife. It appears to be quite slippery to the touch, but actually has rather high friction. This is clearly indicated by the ease with which rope burns are inflicted by polyethylene ropes. When used for tow ropes, this becomes a distinct problem. Its elongation is similar to that of nylon.

European manufacturers have developed a climbing rope that claims to possess qualities that make it superior to all others It is made of *Perlon*, a continental trade-name for a plastic similar to nylon. This *kernmantal* (literally "jacketed-core") rope consists of a core of continuous filaments covered by a woven jacket of the same material. While the jacket may puncture or tear in use, usually enough of the jacket remains to securely hold the core fibers. Its construction is very similar to that of "550" parachute cord. The breaking strength is quite high, but no greater than the most modern American ropes.

During the following twenty years, the development of superior nylon-type yarns, such as the change from *type 300 bright multifilament nylon yarn* to such yarns as *DuPont type 707* have resulted in a much stronger basic yarn. Early nylon ropes were manufactured by spinning short lengths of nylon fibers into yarns and thus manufacturing a rope in the same manner that cotton ropes are constructed. These are still being manufactured for use where a rougher surfaced rope is required, and are referred to as *spun* nylon cordage.

Recently manufacturers have designed ropes in which the individual fibers each run the entire length of the rope. This *filament* rope produces much greater strength than the spun yarns. Lately, a rope has been manufactured in which the long fibers are first *plied* into yarns and these yarns are *set*. The yarns are then woven into ropes, being twisted in the opposite direction as the *plied* yarns, and then the entire rope *set*. Such ropes have approximately 50% greater strength than the war-time ropes listed in Table I. A list of the most recent values of current ropes and webbing is given in the following table.

TABLE II

TYPE & MNFGR		TRADEMARK	SIZE	BREAKING	LBS/100 FT.
commercial grades *		manila	5/16"	1050 lbs.	2.9 lbs.
			7/16"	1750	5.3
NYLON					
Columbian	"Stabilized"	spun nylon	5/16"	1750	2.6
			7/16"	3400	4.8
	"Stabilized"	filament	5/16"	2750	2.5
			7/16"	5200	5.2
	"STALONg"	plied filament	3/8"	4000	3.7
			7/16"	5500	5.0
Plymouth	"Goldline"	filament	5/16"	2300*	2.8
			3/8"	3300*	3.9
			7/16"	4400*	5.4
DACRON					
Columbian	"Stabilized"	spun	5/16"	1500	2.6
			7/16"	2850	5.4
		filament	5/16"	1870	2.9
			7/16"	3570	5.7
POLYETHYLENE					
Columbian		laid	5/16"	1550	2.1
			7/16"	2700	4.0
MISCELLANEOUS					
ASMU	"Perlon"	kernmantal	7/16"-(11mm)	5500	4.7
Aircraft		nylon webbing	1" flat	2500	2.6

*more recent values have been published in catalogs, showing a higher breaking strength.

* special "balloon" and "yachting" grades showed higher values, but have been displaced by synthetics.

Most climbers use a 7/16" rope for climbing. With manila, this only provides minimum necessary strength. With the development of nylon, it was thought that a lighter rope would suffice, and some climbers attempted to get by with a 3/8" climbing rope. Except for safety ropes, not intended for serious climbing, few ropes of this size are now used.

Currently, kernmantal ropes are highly recommended because their construction allows them to run through carabiners and across rock more easily than the twisted nylon ropes. This feature of minimum friction is extremely important when rope-drag becomes critical at the end of a long lead. Kernmantal ropes have the additional advantage of protecting the important inner strands with an outer sheath. Kernmantal ropes, usually made of perlon have approximately the same elasticity as nylon climbing ropes. However, the perlon does not show much of its elasticity until several hundred pounds have been applied to the rope. Nylon, on the other hand, stretches a great deal under the weight of the human body. For example, if one climbs a 150-foot nylon rope, this rope will stretch 20 feet before the climber leaves the ground. Hence, perlon is far superior to nylon for prusikking.

A popular diameter of kernmantal is 11 mm, equivalent to 7/16". This size is rather heavy; 9 mm. seems strong enough, but the thinner the rope, the more easily it can be cut. A 10 mm. rope seems to be a good compromise. In Europe, many alpinists climb with a double 9 mm rope, feeding the strands alternately through carabiners. Americans consider this method unnecessarily complicated, but the double-rope technique has saved lives in areas like the Dolomites, where the rock is sharp and can easily cut the rope of a falling climber.

Another advantage of kernmantal ropes is that there are no exposed strands for tiny rock crystals to work between and damage the rope.

Both 5/16" and 1/4" are used for rappelling with a doubled line. The smaller rope as half the area of a 7/16" line, so that a doubled rope should show the same friction and body contact pressures as a 7/16" rope. A 5/16" line has half the cross section and half the strength of a 7/16" rope.

Webbing provides a binding that is lighter in weight, but still provides a large surface area. Ideal for slings, it is not suitable for a climbing rope, as it tends to snag in cracks, etc.

Very small nylon cords, such as '550' parachute cord are often used for auxiliary cordage for lowering rucksacks, lashing a carabiner to a rock, etc. It tends to snag and should only be used with a full awareness of its problems. Small 1/8" nylon line, often dyed bright red or orange, is used for avalanche cord. A 100 or 200 foot length is allowed to trail behind while traversing dangerous snow slopes, with the hope that if a climber is buried in the snow, some of the cord will be left exposed and will lead rescuers to the victim.

Friction

Tables of weight and strength are commonly given as important factors in the selection of a climbing rope. *Friction*, a most important factor is seldom listed. It is this property of fibers that determines the actual strength of a rope, as this is largely determined by the internal friction between the fibers within the rope. It is the external friction that enables us to tie a knot that will hold, and conversely hinders us when we attempt to untie the knot later. Friction of a rope over carabiners, rocks and clothing also enter into climbing practices. The friction of natural fibers usually increase when wet. Synthetics absorb little water and hence there is little change in the frictional properties of a nylon rope when wet. The often repeated statement that one cannot prusik on a wet nylon rope is not borne out by measurements. Anyone who has tried to untie a knot in wet nylon will bear witness that friction exists.

Friction is a rather variable factor, depending, it is believed on microscopic irregularities in the surfaces. True friction does not vary much with the ordinary roughness of the surfaces. For example, a piece of very smooth rubber and a piece of plate glass will exhibit a high coefficient of friction. A lugsole on soft sandstone may show less. Again within rather large limits, the loading has very little effect.

The coefficient of friction is the ratio of the friction load to the weight load a pair of surfaces will produce. A 1.00 CF means that an object will remain at rest on a 45° slope. The following values were obtained experimently and may vary with various similar specimens. However, the values given are similar to other published results.

TABLE III

COEFFICIENTS OF FRICTION FOR CLIMBING SURFACES

surface	nylon rope		manila rope	
	dry	wet	dry	wet
nylon rope	.60	.61	.51	.78
manila rope	.51	.78	.50	.83
wood, pine	.56	.67	.41	.80
dural alloy	.60	.62	.51	.70
sandstone, arizona	.93	.81	.78	.90
granite, freshly fractured	.65	.78	.51	.79

Knots

Basically, a knot is a configuration in ropes to join two lines together, or to fasten a rope into a loop or onto some other object. Reliability and ease of tying and/or untying are of great importance. It has been said that a climber's knot should be so simple that a climber could tie it in the dark while he is half asleep. At times it must be possible to tie into a rope or sling with one hand. A simple knot, together with enough practice to make tying almost automatic, is indicated.

The number of knots, bends and hitches is almost unlimited. Elaborate knot boards showing beautiful and complicated knots are attractive decorations. However, the number of knots used by climbers has been steadily decreasing. It is possible to climb successfully with but two knots, the overhand knot, and the bowline, if all variations are included. Many of the knots here shown may be derived from these two. However, knots based on the figure-eight have many advantages and they likewise are shown here. Some other standard knots are also included.

There are knots that show up well on a testing machine, but have not found favor with climbers. An example is the double carrick bend. It has the highest breaking strength of any standard knot, but is awkward to tie. Except for use with heavy hawsers in shipping, it is seldom used, and even then the ends must be secured. Yet if one was to go by the tables, this would be the knot.

In the following table, the figures for the knots were obtained by using 5/16" nylon rope, the carabiner figure with 7/16" nylon rope.

TABLE IV

RELATIVE STRENGTH OF KNOTS

Double carrick bend	71%
Sheet bend	65%
Fisherman's knot	59%
Square knot	54%
Double bowline	69%
Bowline	65%
Butterfly	63%
Overhand loop	49%
Carabiner and rope	79%

It would seem that a knot has only about 50% of the strength of a new rope. In actual climbing experience, it is almost unknown for a rope to break in the knot. The ropes break at some old cut, where the rope passes over a sharp rock, or perhaps in an apparently sound section of the line that may have at some time been subjected to a severe strain. Notice, too, that the breaking strength of the rope passing over a carabiner is greater than the more common knots.

Knots have many names, as many as five not being uncommon. We will use the term *knot* both as a general term and for fastening device. A *bend* is used to tie two ropes together. The term *loop* is used for a fixed or non-constricting circle of rope, while a *noose* is a circle of rope that will slip and tighten. A *hitch* is a knot that grips a shaft or another rope. Unfortunately some terms are so well established that it will not always be possible to stick to the above usage. When no name has become standardized, the name used will be that which is most descriptive. For example, *overhand bend* is much more explanatory than is *water knot*.

TERMS USED IN ROPE WORK

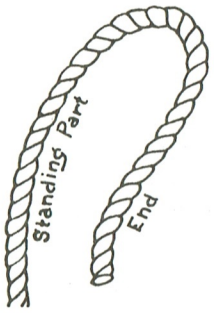
a. The *running end* of the rope is the free end, commonly called just the *end*.

b. The *standing part* is the fastened part of the rope, the whole rope, and may be called the *line* or simply the *rope*.

c. A *bight* is a simple turn of a rope which does not cross itself.

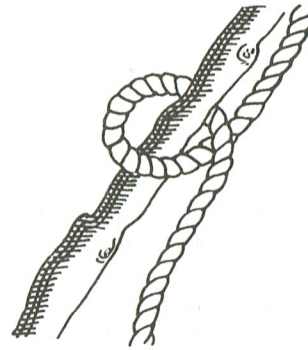
d. A *loop* is a turn of rope that does cross itself.

e. A *half-hitch* is a loop which runs around a shaft, or a piece of rope, so as to lock itself.



bight

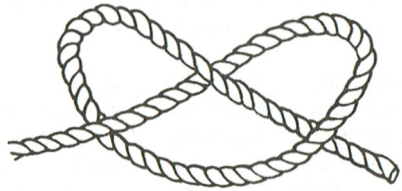
loop



half-hitch

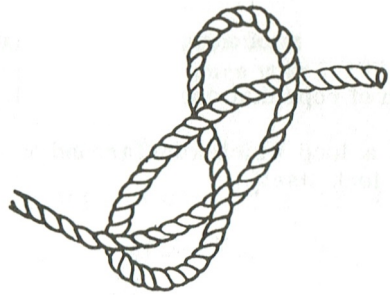
Two other basic knot-forms should be learned, as they are often used in conjunction with other knots and are used to construct more complex knot configurations.

OVERHAND KNOT



A loop is formed and the end passed through the loop. This, the most fundamental knot, is really easier to tie than to explain. It is used as a temporary stop on an unlashed rope end and to provide an enlargement along a rope to supply a better hand hold for climbing a single line. Modern climbing practice suggests that the ends of any knot be secured if the knot is subjected to intermittent stresses. The overhand knot is faster to tie and is more secure than two half-hitches for this purpose, and is being increasingly used in place of the hitches.

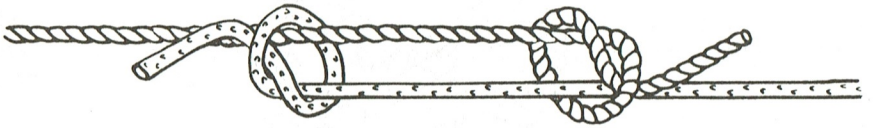
FIGURE-EIGHT



If the end is led behind and around the standing part of the line, before passing through the loop, the figure-eight knot results. It is bulkier than the overhand knot, but forms more gentle turns in the rope and is much easier to untie.

This is an attractive appearing knot and is often used to decorate or border knot display boards.

FISHERMAN'S KNOT



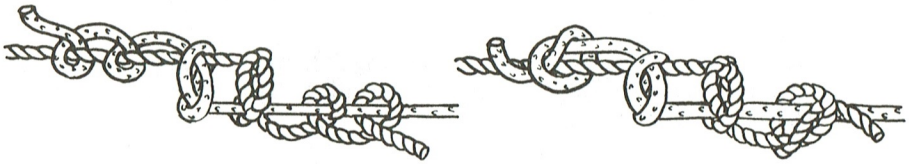
Tying an overhand knot in one end of a rope, then passing the end of another rope through this knot and tying a second overhand knot around the standing part forms a fisherman's knot. Many climbing books refer to this as the Englishman's knot. The two overhand knots should be slid together so that the flat sides are parallel.

This knot may be used to tie two ropes of quite dissimilar materials together, such as a braided rope and a woven rope. It was originally used to tie a piece of gut to a fish line, where most common knots completely fail.

FISHERMAN'S KNOT SECURED

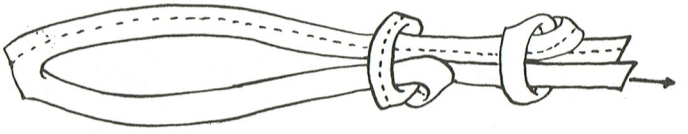
Under hazardous conditions, this knot should be secured. Either two half-hitches are tied around the standing part of the other rope, or one overhand knot is so tied. The overhand knot is easier to tie and more reliable.

The fisherman's knot, properly secured is one of the safest means of joining two ropes. If jammed tightly, it may be a little difficult to untie. In this case it will often be simpler if some rope is forced back into the knots in the opposite order than which it was originally tied.

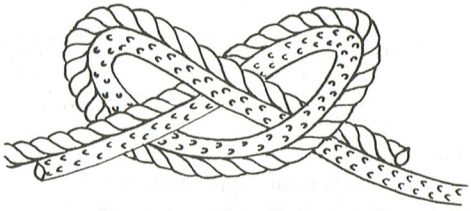


FISHERMAN'S LOOP

This knot may be used to construct a secure loop. WARNING: If the two overhand knots are placed in the wrong order, this knot becomes a noose.

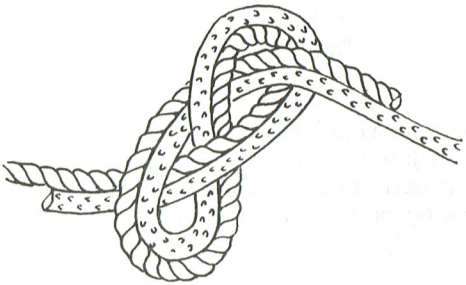


OVERHAND BEND



This is a secure knot, and may be tied in two different ways. If the ends of the rope are available and if it is not important which line carries the strain, a simple overhand knot may be tied in the doubled rope. If the ends are not available, or if it is important that the strains are parallel to the ropes, the knot is tied by first tying an overhand knot in one rope, then leading the second rope end along the first until the knot is formed. This knot works well when tied in webbing. It is called a WATER KNOT in some texts.

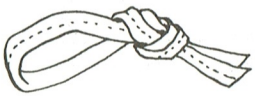
FIGURE-EIGHT BEND



If this knot is based upon the figure-eight knot, it makes for a more symmetrical knot and is much easier to untie. This knot is also called the FLEMISH BEND.

OVERHAND LOOP AND FIGURE-EIGHT LOOP

These knots may be used to construct loops, by simply tying them in bights. If it is desired to tie the rope around an object, it may be easier to first tie the knot in one rope, then lead the other rope end through the first knot. The overhand loop is the old climbing knot known as the MIDDLEMAN'S KNOT, now usually replaced by the bowline-on-a-bight. However it works well in webbing and some climbers still favor it. The figure-eight loop is easier to untie.

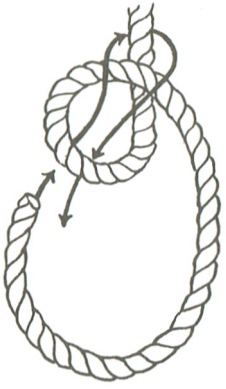


OVERHAND NOOSE AND FIGURE-EIGHT NOOSE

The common "slip-knot" is formed by leading the rope back through an overhand knot tied in the end of a rope. The figure-eight noose is similarly constructed.

BOWLINE

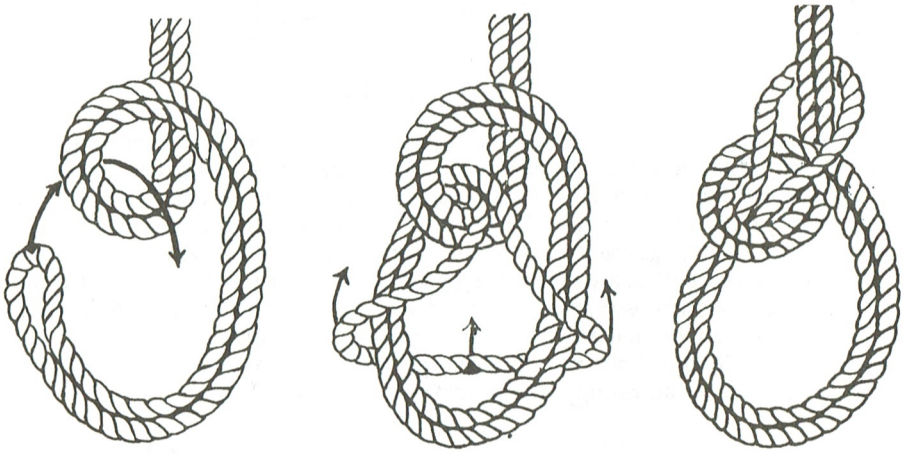
Often called the "king of all knots," this is the basic climbing knot, but is equally respected by cowhands, sailors and all others that use knots. All groups that use the knot have come up with different ways of tying this knot, depending on the size of rope used and the purpose of the knot. One of the best arguments we gave ever heard was between an old cowpoke and a retired sea captain as to the "only" way to tie or bend a bowline. The diagram shows a standard way of tying this knot. Fortunately, if this knot is tied wrong, usually no knot results. However, it is possible to tie this knot with the end on the opposite side from the standing part, and by so doing, about half of the strength is lost.



This knot is used to secure an end man, to provide a non-slipping or tightening loop. or conversely to tie a small loop to form a non-jamming noose. If the loops of two bowlines are tied through each other , it may be used to join two lines together. It is easy to untie and may be used thusly to join ropes of dissimilar materials together.

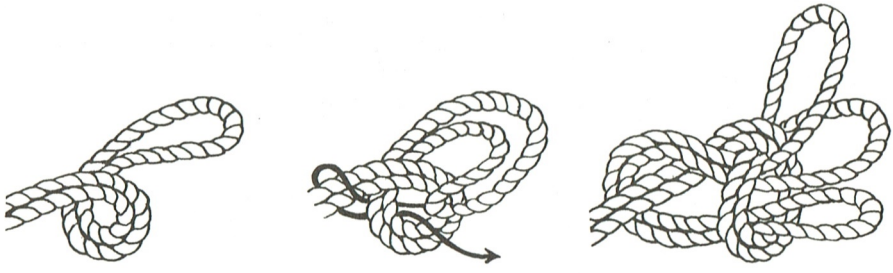
BOWLINE-ON-A-BIGHT

This knot has largely supplanted the butterfly knot as a middleman's knot and is often used for the lead man. The doubled line around the climber's midriff increases the area of contact with the tender parts of the body, and so makes for a more comfortable and safer knot, if a fall must be suffered.



THREE-LOOP-BOWLINE

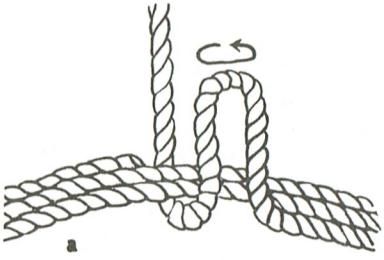
The three-loop-bowline provides three bights, two of which can be adjusted against the third. It is used as a junction knot for 4-piton anchors and may be used to provide multiple lifting points for attaching a litter.

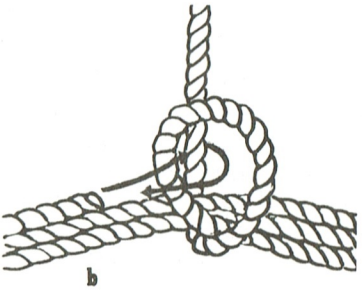


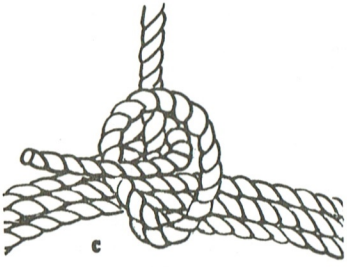
BOWLINE-ON-A-COIL

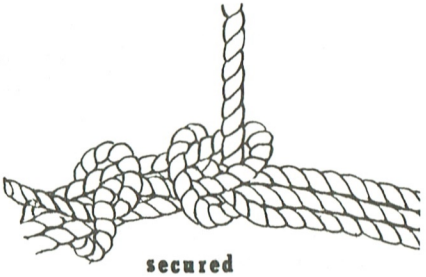
The bowline-on-a-coil is often used by the end man to take up slack in a climbing rope. It provides a much wider bearing surface around the tender middle, and hence the extra rope is used to an advantage.

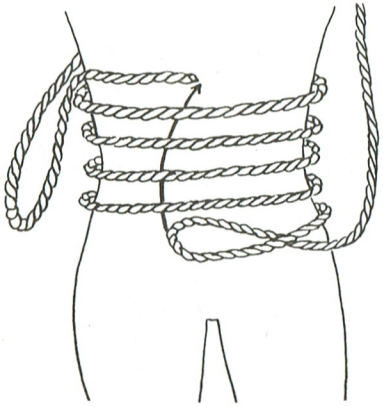
It may also be used to provide extra loops for lash-ups and slings where more points of connection are desired. When so used, it tends to equalize the tensions.

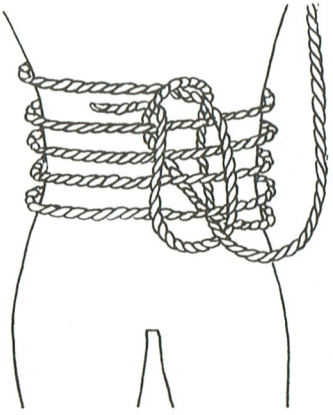




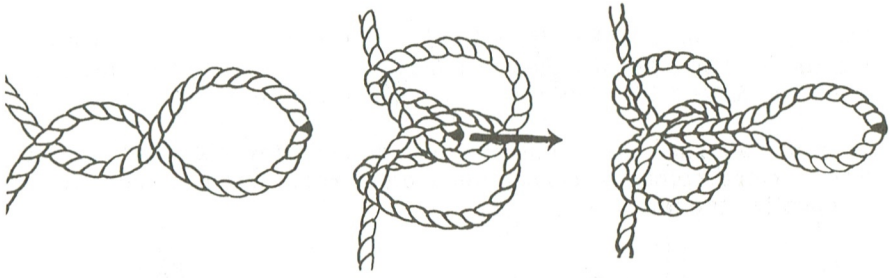






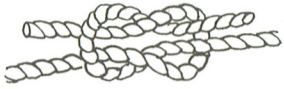


BUTTERFLY KNOT



The butterfly knot has lost much of its earlier popularity being commonly replaced by the bowline-on-a-bight. It was formerly used to tie a middle man into a line, but as it provides but a single coil, it is more painful in case of a fall. However in traversing snow-fields, where the chance of an extended fall is remote, it is still used. It is also recommended to form a small loop in a line as a tie-in point, either directly or with a sling or a carabiner.

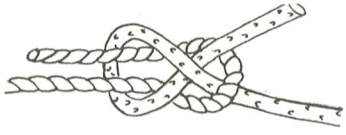
SQUARE KNOT

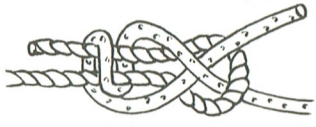


This knot, well known from our Boy Scout days, is suitable for tying packages or dunnage. It is not satisfactory for joining two climbing ropes, nor for use where the strains vary considerably. If it is used for this purpose, it should always be secured.

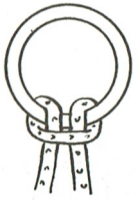
SHEET BEND

This knot also known as the "weavers knot" holds very well with a steady pull. It may be used to tie dissimilar ropes, but if used at all in climbing, the more elaborate form, called the "double sheet bend" is a must.





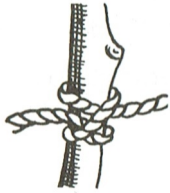
RING KNOT



This knot, called a "girth hitch" by packers, is the most satisfactory hitch to tie onto a shaft cinch ring or another rope. If tied in a doubled rope, there is absolutely no way in which it can loosen. If the post has a convenient open end, the knot may be formed about the fingers and dropped over the post. If to be tied through a ring, one end is fed through, around, across and back through, so that the two ends lie parallel and adjacent. It was from this knot that the prusik knot was developed.

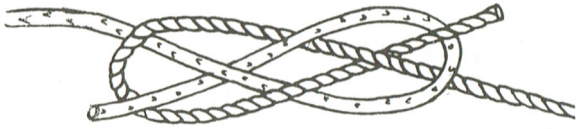
TWO HALF HITCHES

Commonly used to fasten a rope to a post or onto another line. Also used to secure the ends of a knot for greater security. For the first purpose, the ring knot is superior, for the second, an overhand knot is now preferred.



DOUBLE CARRICK BEND

This knot shows up well on a testing machine, but has never been accepted by climbers. It was designed to join heavy ship's hawsers.



ONE-WAY KNOT

The problem of forcing a knot through a carabiner can be serious. If the rope is new and stiff, it may be difficult to pass the knot, especially if it jammed before an attempt was made to feed the rope past the constriction. An old rope may become fluffy and enlarged and so jam. If the rope is wet, cold, or icy, and if the climber is likewise wet, cold and fatigued, the problem may become acute.

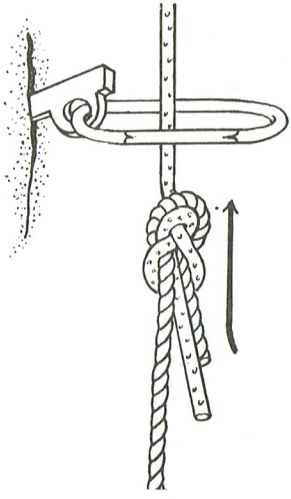
For years, a knot known as the "binder-twine knot" has been used by farmers. It may be quickly tied and will feed through the mechanism of a grain binder. All ends, but one, are on one side of the knot, leaving no loose ends to jam. However binder-twine is a small coarse hemp twine, quite rough, and almost any knot would hold. This knot would not be recommended for use in nylon climbing lines.

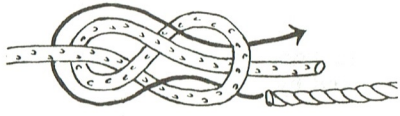
The following knot likewise has both short ends on the same side of the knot. It may be tied in nylon ropes of the same or different sizes. It seems to hold well, but if in doubt, the loop end may be secured with a simple overhand knot, without increasing the diameter of the knot. If tied in 7/16" climbing rope, it feeds easily through a carabiner. If tied with a 7/16" rope and a 5/16" rappel rope, it simply falls through the opening.

This one-way knot is most easily tied by first tying a figure-eight knot in one rope. The second rope end is then fed up through the lower loop around and behind the line, then back down through and parallel to the entering rope. (fig. a). Secure if needed.

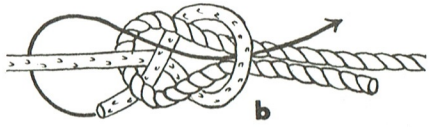
If you like the most conventional type of knot, this one-way knot can be formed from a simple bowline, by tying it with a long end, then leading this end up, behind, and down through the bowline loop. (fig. b)

WARNING: Do not try to feed this knot through a carabiner in the reverse direction.





a



b

FRICTION KNOTS

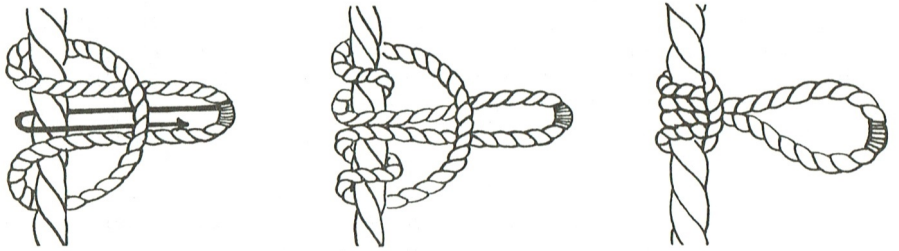
Several knots have been developed that grip a rope while under tension, but release when the load is removed. These serve as a sort of ratchet or clamping device. The first of these was the ring knot. This has limited gripping power and is not reliable in this application.

PRUSIK KNOTS

This hitch is commonly referred to as a 'knot' by climbers. In normal practice it is used to tie a smaller rope, usually in the form of a loop or a sling, onto a larger rope. It grips the main line very securely if under tension, but is easily slipped along the line, if the pressure is released.

To prusik up a rope, one ties small loops of 5/16" or 1/4" around the climbing rope, using prusik knots. One may use either two or three slings, but since two slings are simpler, it is preferable. One attaches other, longer, slings to these prusik knots and then uses these longer slings for the feet and waist or chest. If one uses two prusik knots, one knot is for a foot, the other is for the second foot and the waist or chest. Thus, by applying ones weight alternately between the two knots, it is possible to slide the unweighted knot upward and so climb the rope. The length of the slings for the feet and waist will vary according to the steepness of the prusik. If one is using two prusik knots to climb a rope dangling freely in midair, one will probably want a short sling attaching the waist to the top prusik and a long sling attaching a foor to that knot. The other foot will be used in a shorter sling.

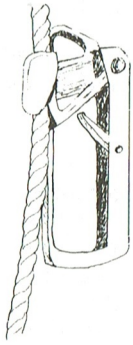
Another way to make a prusik knot hold better is to pass the loop through itself three times instead of twice. The closer the diameter of the sling approaches that of the fixed line, the greater the danger of slippage.



If one carries 'aid slings' and wears a Swami Belt or chest harness, the problem of having the necessary gear for prusikking is simplified. The aid slings, used for the feet, are attached to the knots with carabiners, and the Swami Belt or chest harness is attached with an extra loop of rope and a carabiner.

One should carry prusik equipment whenever there is the slightest possibility of needing it. A climber should practice tying this knot using but one hand, in fact, should be able to make a one-hand tie with either hand. If it is necessary to support oneself with one hand, or if a hand or arm is injuried, this may be the only way the prusiks can be attached. Then practice prusikking in a safe place, so you will have the skill to do it if an emergency requires the ability to climb a rope out of danger.

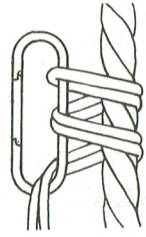
JUMARS



Highly efficient prusik 'machines' are now available. These mechanical devices, which work on the prusik-friction principle, have great utility in extraordinary situations, such as one finds on some of the long climbs in Yosemite. Their general usefulness is limited, due to their weight and expence. The 'Jumar' is the most efficient device now available, but beware of prusikking with Jumars on a rope strung diagonally.

BACHMANN KNOT

The prusik knot is hard to grip or loosen with cold wet hands. An attempt to modify this knot to include a carabiner as a handle was developed in Austria. However it was not too successful, and the more recent development of Jumars has about displaced the Bachmann Knot.

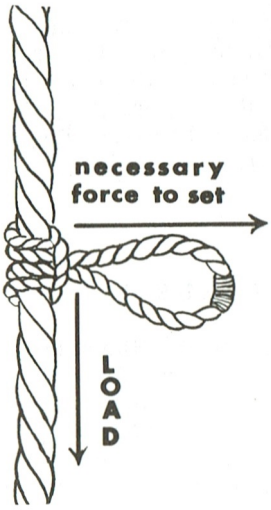


Values of various sizes of standard ropes, cords and other lines are given below. This table shows values for the commonly used ropes, not the high-strength special climbing ropes.

TABLE V

SIZE	STRENGTH	WT/100 ft.	USE
1/2" rope	6600 lbs.	6.6 lbs.	heavy duty climbing
7/16" "	4700	5.0	standard climbing
3/8" "	3200	3.5	light duty climbing
5/16" "	2400	2.6	rappels, slings
1/4" "	1750	1.7	slings, utility
3/16" cord	550	7 oz.	utility, avalanche cords
1/8" "	250	4 oz.	utility.

SETTING FRICTION KNOTS



If pliable small slings are used, such as a 5/16" loop, on a larger pliable climbing rope, the knot grips without trouble. If a hard-laid rope of larger diameter is used, such as a 7/16" sling on a 7/16" rope, it may be difficult to get the knot to conform to such a relatively small diameter. If a spun-nylon hard-laid rope becomes wet, it stiffens and the knot may fail. This is not due to a change of frictional qualities.

Much of the tendency of a prusik to slip is due to the 90° angle between the needed tightening force and the load-line. If, when setting the prusik, the thumb is placed against the knot while the fingers grip the sling, it is possible, with almost no effort, to tighten the knot, as the load is allowed to come onto the line. If this first "snubbing" friction is applied, then the total load will further tighten the knot, when it is added.

CARABINERS

Originally, carabiners or snaplinks were used solely as a means of snapping a climbing line onto a piton. It was faster and easier than attempting to thread the rope through the eye of a piton.

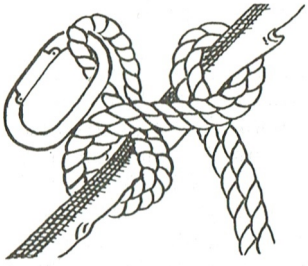
In modern usage, the carabiner often substitutes for a knot. It may be pointed out that a 7/16" rope-carabiner combination has 79% of the breaking strength of the nylon rope. The strongest knot, the double carrick bend has but 71%, and the average knot has near 50% of this strength.

Often a sling may be better made of two types of materials. A prusik sling may consist of a short loop of 5/16" rope to grip the climbing line and a longer loop of webbing to provide a more comfortable foothold. A carabiner is the logical way to join the two.

In rescue work, a number of light slings may be clipped to a bowline tied onto the end of the main line.

In some cases, a carabiner may be snapped through a knot, serving solely to anchor the knot and preventing its slipping.

In general, at any time, when a rope must be fastened and unfastened a number of times, if a carabiner may be included in the circuit, the task is much simpler.

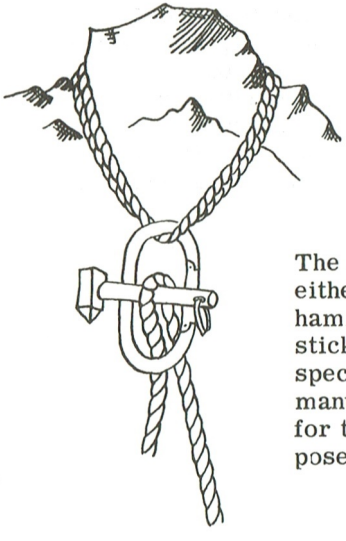


STUNS'L TACK BEND

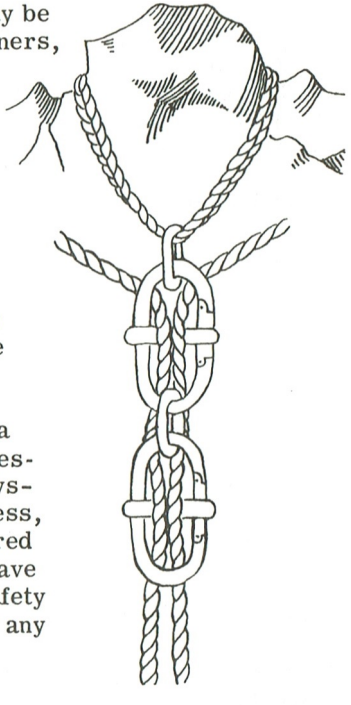
An example of a knot so secured is the stuns'l tack bend. This knot, a pair of half hitches, tied in a bight, is an excellent knot to tie onto a tree or a pole. But it can work itself free. A carabiner snapped through the eye positively secures the knot.

FRICTION BRAKES

Although not true knots, the friction brakes are used in conjunction with the friction knots in rescue work, and for other times, when it is necessary to lower a heavy load under complete control. The brakes are quite easily constructed from the drawings.



The cross-bars may be either other carabiners, hammer handles, sticks, or the special bars manufactured for this purpose.



The single carabiner brake supplies a very limited amount of friction, and most of the load must be supplied by standard belays,

The double carabiner brake supplies quite a large amount of friction, and it may be necessary to actually feed the line through the system to get the load to descend. Nevertheless, it should always be backed by a well anchored belayer. In rescue work, the workers have very limited freedom of motion, and the safety measures must be adequate to take care of any emergency.

Slings

Originally, a rope was the rope. It was carried or used as was necessary. Harnesses were fashioned by loops and knots in the rope end. If it became necessary to tie onto a rock belay point, the climbing rope was looped over the rock formation. But, shortly, it was found that it was better to tie a sling around the rock outcropping and then pass the climbing rope through this sling. Then, after roping down a face, the climbing rope could be retrieved, leaving a small length of sling rope.

With the coming of the much more expensive nylon lines, it became common practice to fashion the sling of manila or some other less expensive material.

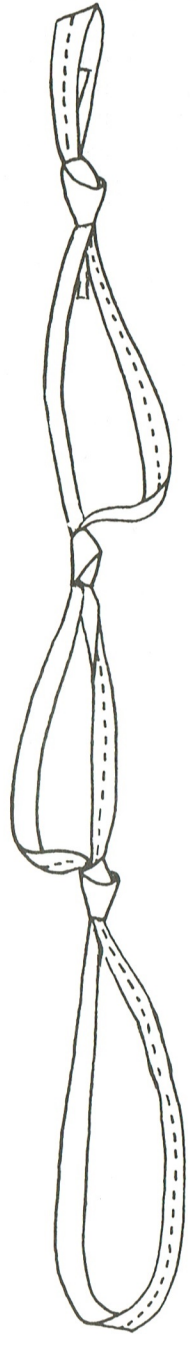
If a chest harness were tied in each end of a 100 foot rope, 20% or more of the rope could be used up, just to fashion these harnesses. Special lash-ups might take as much as 20 feet of line. Such harnesses could be fashioned of short rope-lengths and then clipped to the climbing rope with a carabiner. This had the further advantage that if the climber wished to wear a rope for only part of a climb, the harness or loop could be left on and the climbing rope snapped quickly off and on. In more recent years, it has been found that nylon webbing makes a more comfortable harness and by this method, the harness could be made of a lighter weight material than the climbing rope. Prusik slings are better made of smaller rope than the climbing line.

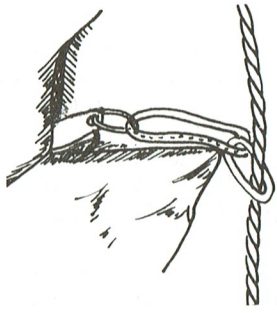
The basic sling is a simple short length of rope or webbing, fashioned into a loop. Common sizes are 18 inches, three, six or ten feet. Some uses are: around a chockstone or tree as a belay point, as a piton extender or shortener, as a rappell or chest sling, prusik sling, etc. Recommended for direct aid slings is a piece of webbing, one inch wide and 16½ feet long, tied in the manner shown in the sketch. Many climbers prefer 15 foot lengths for 3-step slings. This way of preparing an aid sling, invented by Tom Frost, eliminates an extra knot. (In the high mountains where it is important to travel as lightly as possible, one may use 1/2" webbing, but it is less comfortable and more difficult to use.)

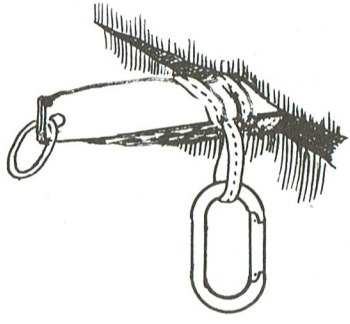
DIRECT-AID SLINGS OR STIRRUPS

The original direct-aid climbs were called 'tension climbs', for the climber was literally pulled up to each piton in turn. The formation of long three- or four-step slings now enable a climber to place his pitons six feet apart and climb as on a ladder. (Note: the knots are tied to one side, so as to form a flat step.) These rope ladders, often called 'aid slings' or 'stirrups' are now a stock tool for this type of rock work.

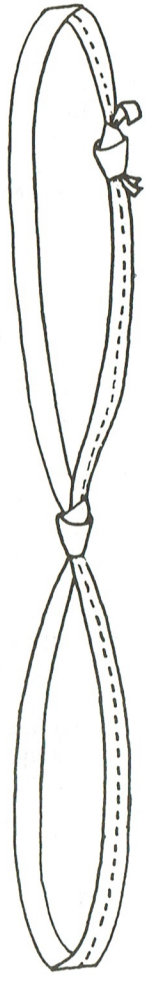
Frost 3-loop sling

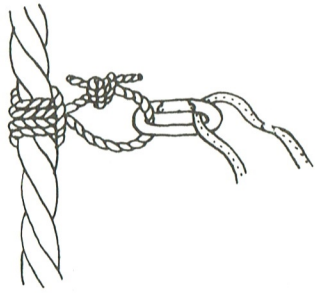


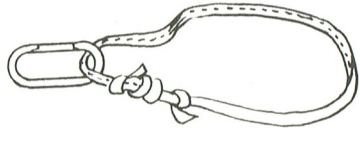




2-loop sling



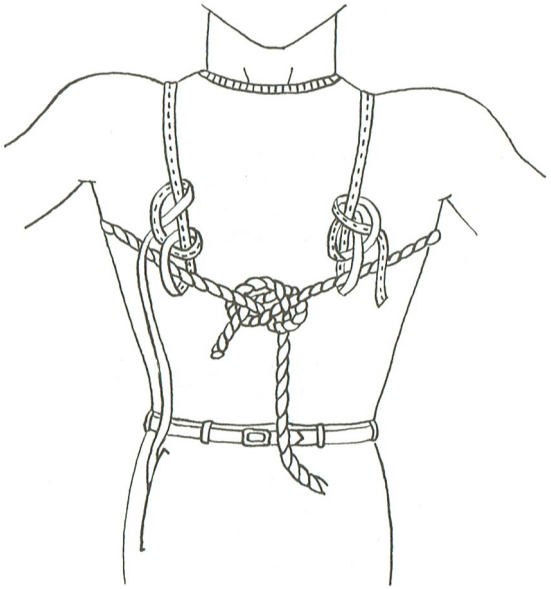


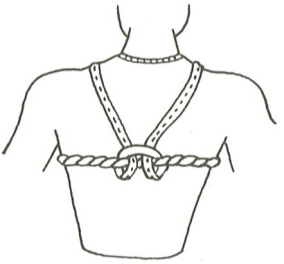


Harnesses & Swami Belts

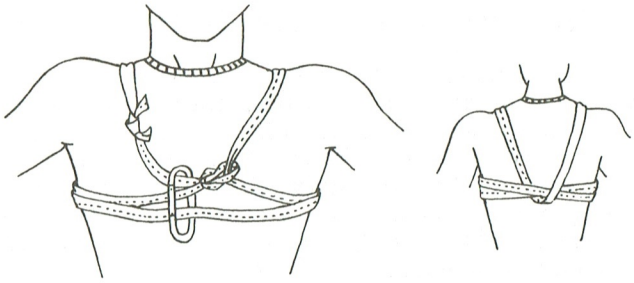
In the Western Hemisphere, most climbers tie onto a rope with some form of a bowline. This will hold a falling climber without undue injury, if the fall is arrested with a dynamic belay. In Europe, the dynamic belay is not so completely accepted. As a result, there has been developed a system of chest harnesses that cause less body injury if a fall is arrested by a static belay. The simplest consists of a simple loop around the chest. However the chest structure is such that this slips down the instant the tension is released.

A satisfactory harness is constructed by tying a bowline in the climbing rope at the center of the chest, then tying a lighter line or webbing onto this rope in the front, then over the shoulder and onto the back part of the loop with a ring knot, then back across the shoulder and onto the loop in front.





A separate chest harness may be formed of sling material, by taking one, two, or more turns around the chest and tying with a bowline, leaving a four foot end. This is passed over the shoulder, around the back of the chest loop, and then back over the other shoulder and tied again in front.

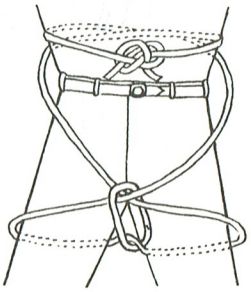


Theoretically safer, chest harnesses are little used in the United States, because they are considered cumbersome. Another disadvantage is that the harness must be removed in order to shed or put on clothing.

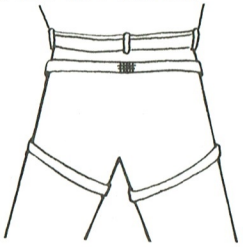
The 'Swami Belt' seems to provide a good compromise between comfort and simplicity. It is simply a length of nylon webbing, 15 to 30 feet long, wrapped around the waist and tied with a ring bend. Normally, the climbing rope is tied directly to the Swami Belt. An important advantage of the Swami Belt or the chest harness over a normal tie-in is that it provides a convenient means of anchoring oneself to pitons or other security point when one is not tied to the climbing rope, as on a rappel. Swami belts were first devised by Yvon Chouinard and 'TM' Herbert.

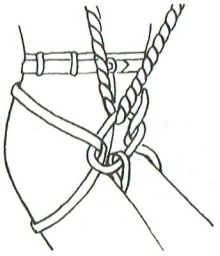
Both Swami Belts and harnesses provide a greater area of contact than a normal tie-in. The harnesses put the load on the stronger rib cage, and a victim of a fall lands more nearly in an upright position, lessening the chances of a head injury. An injured person has a greater chance of survival, if he is forced to hang on a rope for a considerable length of time, when his head is in an upright position.

RAPPEL SLINGS



Slings and carabiners can form a more comfortable rappel, at the cost of a certain loss of friction. A sling is draped around the body and gathered through a carabiner. The rappel rope first passes through the 'biner and then is wrapped around the body in the customary manner. If two carabiners are used, the heat generated is more safely dissapated. A simple "diaper" sling and a more elaborate one are shown.





Choosing the Rope

A few years ago, choosing a climbing rope was a simple matter. The rope was a piece of 7/16", 120 feet long, mountain-lay nylon. With the coming of filament ropes, where the strength of a 3/8" rope is greater than yesteryear's 7/16" rope, we found a multitude of choices.

With manila rope, there was no problem in rope design. First class manila abaca has a certain maximum breaking strength. There is but one way to increase the strength of a manila rope; simply force more fibers into the rope during manufacture. This increases the number of fibers and also increases the intra-rope friction. But this also makes for a much harder or firmer rope. Accordingly climbers insisted on a "hard-lay" rope. The first synthetic ropes were constructed by the "spun-nylon" process and again a hard-lay rope meant more fibers and more internal friction and so more strength.

With the coming of filament nylon ropes, with each fiber running the entire length of the line, this no longer was an important factor. Some of the most modern ropes would be called "soft-lay", as due to the setting process, the ropes are pliable and apparently soft to the touch With this type of rope, it is much easier to tie knots, and the knots hold better. Prusikking is safer. It will pass over or through a carabiner more readily. While at first glance, one might think that a hard-lay line would withstand more abrasion, on second consideration, it will be realized that the softer rope, with more of its surface area in contact with the rough rock surface, the pressure per square inch will be less, resulting in less cutting. So many climbers now insist on a pliable mountain rope, such as Columbian's "STAYLONg".

Until recent years the standard length of a climbing rope was 120 feet. About 1960, climbers began using 150 foot ropes in Yosemite Valley. This length of rope was useful not only on the tension routes, but also on the free climbs where the belay ledges are sparsely spaced on the smooth Yosemite granite. The trend to 150 foot ropes has spread. Now, climbers in many regions find this length convenient for their purposes. — at least it seems certain that a rope too long is far superior to one that is just a little too short.

For practice climbing, a 1/2" nylon rope is often used. While the largersize provides more strength, especially in practice ropes that may serve much longer than their normal life span, the larger diameter provides a much larger gripping surface for inexperienced climbers.

If rock climbing is of secondary interest, as in mountain scrambling, the rope-work may be limited to a short belay near the summit or on some exposed face. Or the rope may only be used to provide a static line to assist the weaker members of the party. For such purposes, a 60 foot length of 3/8" nylon will be satisfactory. It will weigh just over two pounds, and may be tucked away in a corner of the rucksack.

AUXILIARY ROPES

Special ropes are often used either separately or in conjunction with the climbing rope for rapelling. Standard sizes are 5/16" by 200 feet, or 3/8" by 300 feet.

1/4" and 5/16" nylon rope and 1" nylon webbing or flat tubing are used to form slings, stirrups, and harnesses. These are often spliced or sewn as more or less permanent items to be carried with the pitons and carabiners.

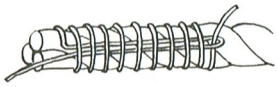
A length of 5/16" *new* manila rope is often carried to fashion rappel belaying slings, and for other single-use purposes. Remember that manila has only about 30% of the breaking strength of nylon, when new, and weathers and ages much more rapidly.

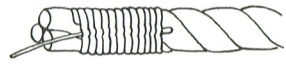
Finally, a 100 foot or a 200 foot length of 1/8" or 3/16" nylon cord such as parachute "550" cord, is useful to haul up dunnage and for other *non*-climbing purposes. If dyed red, it may also serve as an avalanche cord.

PREPARING THE ROPE

After the rope has been chosen and purchased, a little work must be done before it is ready for the mountain. Any rope rapidly frays at the ends unless they are bound. The most secure of fastenings is whipping. Draw the whipping threads tight and this resultant end is worth the effort. A quicker and less satisfactory binding is formed by two or three turns of adhesive tape. Electrician's vinyl tape is recommended. The ends may the be fused by heating over a match or gas flame. Hold the rope end well above the flame, then lower until the nylon flows. It is possible to mold the softened ends with the fingers, but handle the hot ends with the same caution you would a hot potato.

With kernmantal ropes, it is only necessary to fuse the rope ends.





Many climbers further fasten the ends by dipping them in enamel or lacquer. Lacquer softens the fibers and causes them to bind together. (allow 24 hours to dry) While this process weakens the rope, it is of no importance, if the use of lacquer is restricted to the two or three inches at the end of the rope. Do NOT mark other parts of the rope with lacquer or paints.

Lacquer also provides a means of identifying ropes. A series of narrow rings may be painted with various colors - - try model airplane paints - - in the same manner an archer crests his arrows. A broad band may be applied, then each strand painted separately for special identifications. A common practice is to dip the rope ends in black paint when the rope is no longer considered safe for serious climbing.

A middle mark is convenient in handling rope. A small lashing around the rope, or around a single strand is the only approved method of making this mark. Do not use paint or dye on the working parts of the rope.

RETIRED!

Care of the Rope

A climber's rope is a precision tool, used for a skilled occupation. It should be treated with the same care and respectas any other fine instrument. When your life may literally "hang by a thread", too much care cannot be given for its preservation.

Nylon ropes do not weather as badly as manila ropes, and so often, the fundemental rules are ignored. For example, nylon will not mildew. However organic materials,such as lichens and mosses mayrub off on a rope and this material will mildew. Nylon is a plastic and while it is more resistant than some, it is subject to oxidation. Nylon ropes should not be stored in direct sunlight. Normal use in sunlight will present no problem. Oils, spirits, gasoline and lacquer thinners must be kept away from synthetic ropes. Lacquer or lacquer thinner will destroy a nylon rope in minutes.

RULES

NEVER walk on a rope. Stepping on a rope with crampons or triconis is a cardinal sin, usually calling for prompt and uncouth comments.

The rope should not be dragged along the ground. Small rock crystals and fragments will work their way between the fibers and slowly cut the rope in a way that is not visible from the surface.

Do not allow the rope to run over sharp edges if it can be avoided, especially if it is under a heavy load.

Do not store near radiators or other sources of heat, or in a dirty car trunk. Do not hang over sharp nails.

Keep the rope reasonably dry, if possible. Dry before storing.

Do not leave a rope stretched or under tension for any extended period of time.

Remove all tight knots after using and before storing.

Do not use a climbing rope as a car tow rope. Once so used, it is then and forever more a tow rope and never again a climbing rope.

Completely examine a rope immediately after it has held a fall.

Examine the rope at regular intervals. If puffs of fibers are observed at any point along the line, RETIRE the rope. On a climb, a butterfly knot may be tied to isolate the damaged section in its loop.

Examine the rope immediately after it has been hit by a falling rock, no matter how small. If a sudden strain has been placed upon the rope while passing over a sharp edge, examine.

WASHING AND DYING ROPES

Any soap or detergent that is safe for nylon stockings may be used to wash nylon ropes. Both Du Pont and Plymouth Cordage have pointed out that water boils at 212° and that ropes are often heated as hot as 300° F in setting processes, without damaging the ropes. Nevertheless with the elaborate and delicate setting processes involved in making filament ropes, one might well be careful about subjecting this type of rope to boiling water, either in washing or dying. Spun nylon ropes may safely be dyed by household boiling methods.

Du Pont recommends that their yachting ropes be scoured with a mild detergent solution and then hosed clean. Climbing ropes may safely be washed in an automatic washer, using a detergent recommended for nylons, and setting the heat control at "nylon" or "gentle action". Dry

in the shade on an open line.

Aside from the cleanliness and beauty of a freshly washed sparkling nylon climbing rope, this will remove invisible rock crystals and organic materials that tend to shorten the life of your climbing rope.

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A young mountaineer named McPott
Tied an insecure butterfly knot.
He screamed as he fell
(A maniacal yell ----)
"My God! I'll be hardly a spot."
rd

ROPES, KNOTS AND SLINGS FOR CLIMBERS was first published in 1960, the work of Walt Wheelock, who has been a climber of California's mountains for over four decades. It was well received upon publication, as it was the first knot book directed to the climber. The knots were usable, and the drawings were clear; the descriptions short and definitive.

But, since seven years had passed, it was felt that it should now be updated, to include the advances made by our rapidily expanding scientific and technological age. But no less important was the amazing advances made in the attitude and apitudes of a new school of climbers. A man was sought to do the revision who was well known as a climber, a mountaineer editor, and a writer. Royal Robbins, famed for his climbing, both in the U.S. and in Europe, was selected and undertook the revision. Here is the result, this 'best-selling' mountaineering rope and knot book, now updated to the 'free-climbing' techniques that are leading to ascents that could never occur, even in the dreams of yesteryear's alpinists.

La Siesta Press

$1.50